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1970
USDA Forest Service Research Paper PNW-98

AN ECONOMIC ANALYSIS OF ACCELERATED ROAD CONSTRUCTION ON THE BUREAU OF LAND MANAGEMENT'S TILLAMOOK RESOURCE AREA

U. S. DEPT. OF AGRICULTURE
FOREST SERVICE

JUL 15 1970

CURRENT SERIAL RECORDS

BY
CON H. SCHALLAU

A BRIEF SUMMARY OF STUDY

This report assesses the economic consequences of advance roading (accelerating road construction) in order to increase thinning receipts in managing young growth on the U.S. Department of Interior, Bureau of Land Management's Tillamook Resource Area (about 50,000 acres).

Alternative Rate of Road Construction Economically Inferior to Current Program

Presently, approximately 15 miles of logging roads are being constructed annually. At this rate, the entire system will require 16 years to complete. The base program--15 miles per year--was compared with a plan to double the rate of road construction. The 30-mile-per-year construction program was found to be economically inferior to the base program. In fact, investment in such an accelerated program would earn a minus 1.25-percent rate of return. Although advance roading would increase timber production and timber revenues, the additional revenues would not be enough to compensate for higher maintenance, timber sale administration, and interest charges.

Current Rate of Road Construction Supports an Active Thinning Program

The present pattern of logging has a major effect on the economic feasibility of accelerating road construction in the Tillamook Resource Area. The road system will be completed sooner as a result of logging staggered settings rather than a continually receding wall of timber. That is, the current rate of road construction is providing more road than necessary to market the annual allowable cut. In a real sense, therefore, the current rate is "advance" roading, since timber units between staggered settings support an active thinning program.

Accelerated Roding Not Economically Feasible Despite Changes in Assumptions

Basic costs and price assumptions were varied systematically, and the effects of such changes upon the economics of advance roading were examined. For example, reduction in road construction costs would not significantly affect the economic attractiveness of advance roading. Furthermore, increasing stumpage values for thinning would still generate a negative rate of return.

Increasing all costs and revenues 3 percent, compounded annually to simulate inflation, significantly affected the economic feasibility of advance roading. But the rate of return (1.92 percent) does not compare favorably with alternative public investment opportunities.

ADVANCE ROADING--A MEANS FOR INCREASING ALLOWABLE CUT

Since about 1960, public forests in western Oregon and western Washington have been marketing their full annual allowable cut. Because a strong demand for timber is forecasted and because public forests are expected to produce a larger proportion of the region's future log production, public forest managers are exploring alternatives to increase allowable cuts.

Advance roading has been suggested as a means for achieving greater timber production.^{1/ 2/} It would result in increased harvest from prelogging small timber and salvaging mortality in old growth, plus thinning young growth (fig. 1). For example, Fedkiw estimated that between 1960 and the year 2000, an additional 100 billion board feet could be utilized in the Douglas-fir region of Oregon and Washington if road construction were accelerated.

To justify advance roading, revenues from additional timber harvests must cover added interest, maintenance, and administrative costs. Depending upon an agency's or firm's guiding rate of interest, previous analyses of both private and public forest ownerships have shown that advance roading can be economically attractive. In an analysis of private investment, Fedkiw reported "rates of return as high as 10 percent, after taxes. . ." (p. 5),^{3/} but Payne found that public investments in advance roading earned between 2.9 and 3.6 percent.^{4/}

This study gives public forest managers an indication of the economic feasibility of advance roading for managing young-growth timber. It is unique because it considers a situation where thinning yields are the only timber benefits of advance roading. Previous studies have involved either (1) just prelogging and mortality salvage operations in old-growth stands, or (2) a combination of (1) and thinning of young-growth stands.

^{1/} Fedkiw, John. Advance roading for increased utilization in the Douglas-fir region--Oregon and Washington. Western Forest. & Conserv. Ass. Proc.: 51:64-69. 1960.

^{2/} USDA Forest Service. Timber trends in the United States. Dep. Agr. Forest Resource Rep. 17, 235 pp., illus. 1965.

^{3/} See footnote 1.

^{4/} Payne, Brian R. An economic analysis of alternative rates of investment in National Forest road construction: the North Umpqua case. 190 pp., illus. 1969. (Unpublished Ph.D. dissertation on file at Univ. Calif., Berkeley.)

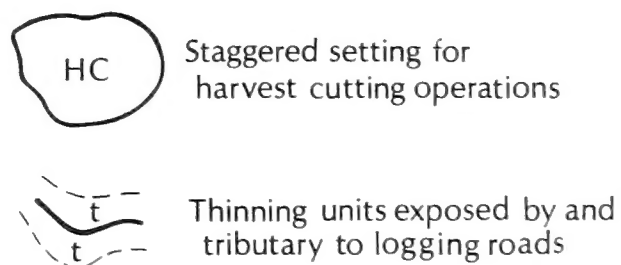
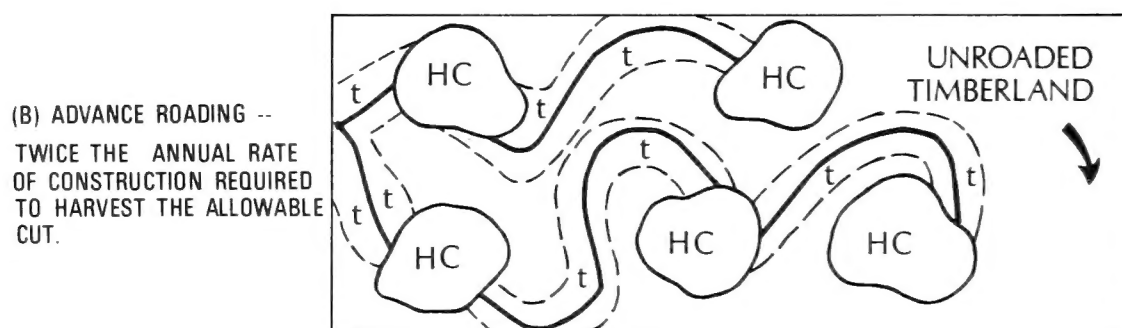
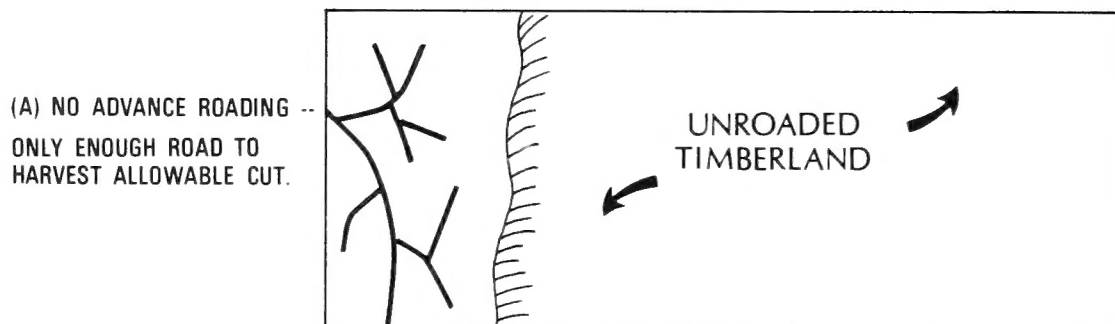


Figure 1.—Harvesting the annual allowable cut from a continually receding "wall of timber" (A) requires less road construction than advance roading (B).

This analysis of young-growth advance roading opportunities was conducted in conjunction with the U.S. Department of Interior, Bureau of Land Management's (BLM) Tillamook Intensive Management Project^{5/} (fig. 2). Here, 196 miles of roads were completed or under contract for construction by December 31, 1967. An additional 300 miles of road will be required to complete the Tillamook project road system. However, only an additional 240 miles will be required in the near future since timber on some scattered, inaccessible tracts will not be merchantable for another 25 to 30 years.

Approximately 42 percent of the resource area's 52,000 acres of forest land is now accessible for logging operations (i.e., "roaded"). At the end of calendar year 1967, 4,563 acres, or 48 percent, of the Tillamook Resource Area's acreage of rotation age (80 years) or older conifer timber type was accessible by road. Of this, approximately 65 percent has been clearcut. Because of the heterogeneous composition of age classes, roads constructed to provide access for clearcutting mature timber also exposed young growth (table 1). This study focuses on the accessibility of thinnable timber. Thinnable timber here is fully stocked, 40- to 70-year-old conifer--mostly Douglas-fir--stands, 60 percent of normal basal area and greater, on slopes less than 45 percent. It is the potential yield from presently inaccessible thinnable stands that will determine the economic feasibility of accelerating road construction. Currently, about 57 percent of the thinnable acreage is inaccessible by road (i.e., "unroaded"). At the present rate of road construction, 15 miles per year, this acreage will not be fully accessible for 16 years.

COMPILATION OF BASIC DATA

The major difference between the base (15 miles per year) and the accelerated (30 miles per year) programs from a construction cost standpoint is the timing and not the amount of investment. That is, the total cost of road construction was assumed to be the same--\$8,824,000--regardless of how quickly the road system was to be completed. In contrast, both timing and amount of timber harvesting activity varied by road plan. The methods for deriving annual timber revenues and costs are reviewed in this section.

Simulation of Road Construction and Timber Harvesting Involved Three-Phase Mapping of Study Area

Determining the acreage of timber type, by species, age, and stocking classes, tributary to new road construction was the major data compilation task. Timber type tributary to and construction costs of the first additional

^{5/} This project was undertaken in 1962 to field test various silvicultural, engineering, and administrative procedures for managing young-growth Douglas-fir forests. The Production Economics Research Work Unit of this Station is assisting the Bureau of Land Management with evaluation phases of this study.

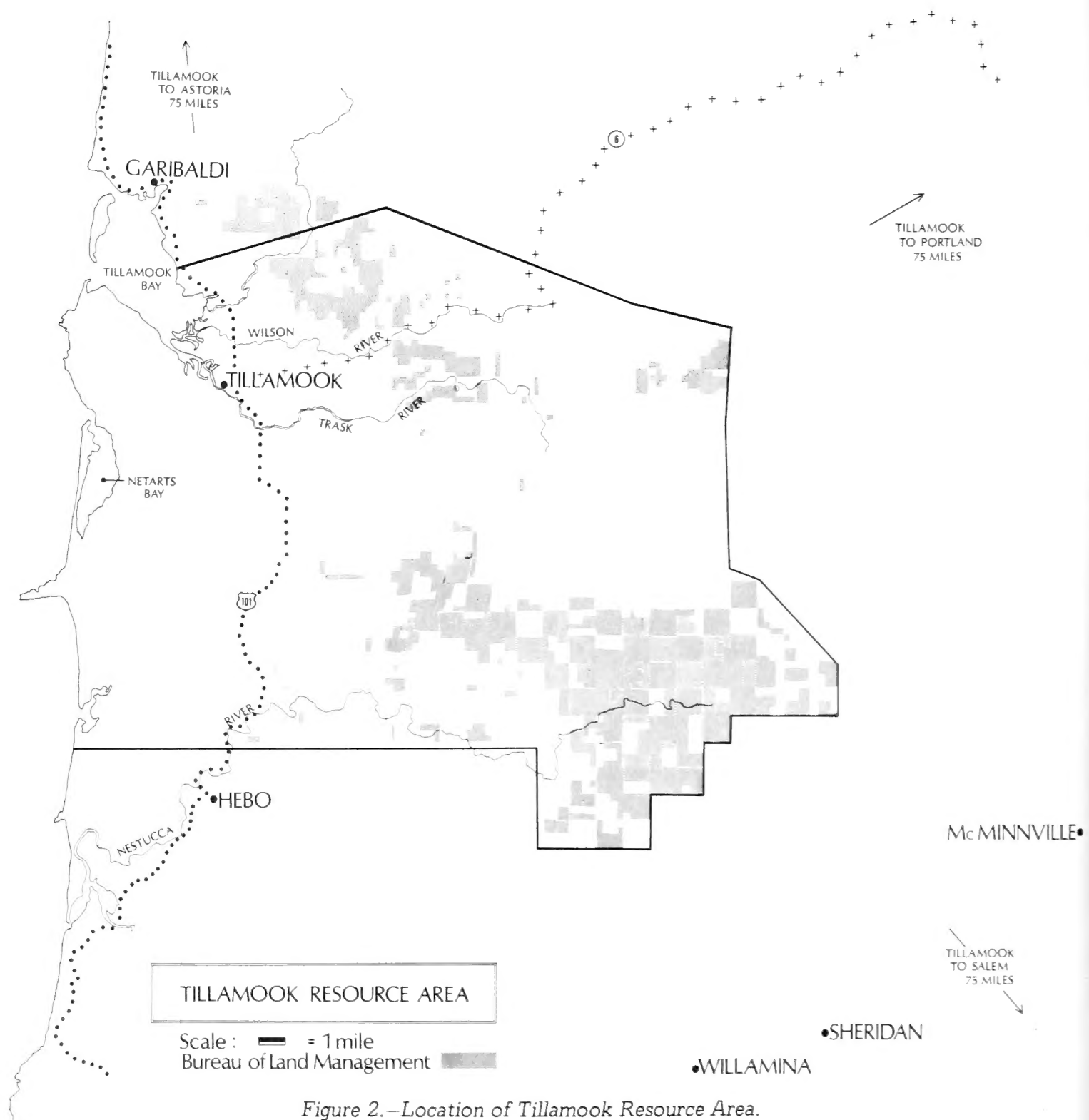


Figure 2.—Location of Tillamook Resource Area.

Table 1.--Acres of accessible commercial forest land on
Tillamook Resource Area in 1967, by forest
type and stocking class^{1/}

| Age class | Douglas-fir stocking class ^{2/} | | | Alder (all stocking classes) | Total |
|-------------|---|---------------|----------------|---------------------------------------|----------------|
| | 10-39 | 40-69 | 70+ | | |
| 0-10 | 156 (56) | 603 (70) | 4,874 (100) | 262 (56) | 5,895 (94) |
| 20 | 29 (60) | 239 (44) | 167 (31) | 143 (23) | 578 (36) |
| 30 | 19 (100) | 110 (53) | 962 (59) | 411 (40) | 1,502 (54) |
| 40 | 15 (68) | 149 (45) | 750 (44) | 908 (32) | 1,822 (38) |
| 50 | 32 (48) | 58 (55) | 89 (12) | 105 (7) | 284 (23) |
| 60 | 40 (10) | 125 (15) | 1,648 (37) | 103 (6) | 1,916 (33) |
| 70 | 85 (19) | 435 (31) | 5,902 (47) | 105 (9) | 6,527 (45) |
| 80+ | (<u>3/</u>) | (<u>3/</u>) | 1,581 (24) | <u>3/</u> 47 (11) | 1,628 (24) |
| All classes | 438 (19) | 2,596 (43) | 15,034 (49) | 2,084 (21) | 20,152 (42) |

^{1/} Numbers in parentheses indicate percentage of type class accessible. Not included are 1,515 acres of nonstocked forest land.

^{2/} Stocking is expressed as percent of crown closure.

^{3/} For purposes of this study, all acreage in the 80+ age class was shown as 70 percent or better stocked even though in actuality there is a limited acreage of lower stocking classes.

mile of road could not be assumed the same as for the last mile in the system. Variability of topography and distribution of forest types, plus the fact that a concerted effort is underway to expose thinnable age classes first, required mapping the uncompleted road system and tributary thinning and harvest cutting units.

Tributary forest acreage could have been determined for each of the remaining 240 miles of road to be constructed in the near future. But such precision was believed unwarranted. Instead, road construction was arbitrarily divided into three phases. Years to complete each construction phase varied by road plan as follows:

| | Rate of road construction (miles per year) | |
|-------------------------------------|---|------------|
| | <u>15</u> | <u>30</u> |
| Years per phase of construction: | | |
| I | 4.7 | 2.3 |
| II | 4.7 | 2.3 |
| III | <u>6.6</u> | <u>3.4</u> |
| Total years to complete road system | 16.0 | 8.0 |

The first two phases each involved 70 miles of road, and the last 100 miles. Classification of the 240 miles of road by phase and type of logging road^{6/} is shown below:

| Phase of construction | Miles to be completed, by type of logging road | | Total |
|--------------------------|---|-----------------------------------|--------------|
| | <u>Access road</u> | <u>Low design- speed road</u> | |
| I | 59.6 | 10.4 | 70.0 |
| II | 5.4 | 64.6 | 70.0 |
| III | <u>11.0</u> | <u>89.0</u> | <u>100.0</u> |
| Total | 76.0 | 164.0 | 240.0 |

Although more road is to be constructed in phase III than during phase I, the first phase accounts for the largest single share of the road investment--43.6 percent versus 33.7 percent. The reason is that considerably more mileage of high cost access road is constructed during phase I than during phase III (access roads cost \$60,000 per mile, whereas low design-speed roads only \$26,000).

As with road construction investment, the amount and composition of forest land exposed by roads varied from phase to phase. Generally speaking, cutting units exposed by early construction contain more conifer type as well as total acres than later construction (table 2). Also, early construction tapped more thinnable timber.

^{6/} Schallau, Con H. An analysis of two logging road standards for BLM's Tillamook project. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-48, 5 pp. 1967.

Table 2.--Total commercial forest land exposed by three phases of road construction, by type and age^{1/}

(In acres)

| Stand age ^{2/} | Douglas-fir, by phase of construction | | | Alder, by phase of construction | | |
|-------------------------|---------------------------------------|-------|-------|---------------------------------|-------|-------|
| | I | II | III | I | II | III |
| 10 | 50 | 67 | 176 | 63 | -- | 34 |
| 20 | 43 | 124 | 270 | 81 | 31 | 90 |
| 30 | 148 | 212 | 345 | 47 | 107 | 197 |
| 40 | 186 | 436 | 513 | 335 | 807 | 585 |
| 50 | 41 | 4 | 417 | 120 | 182 | 1,038 |
| 60 | 828 | 2,106 | 805 | 283 | 201 | 950 |
| 70 | 3,198 | 3,287 | 1,270 | 248 | 180 | 504 |
| 80+ | 2,339 | 1,386 | 1,221 | 310 | 33 | 67 |
| Total | 6,833 | 7,622 | 5,017 | 1,487 | 1,541 | 3,465 |

^{1/} Not included are 691 acres of nonstocked forest land, of which 65 percent are exposed in phase III.

^{2/} Age at beginning of investment period. All stands were updated at beginning of second decade.

Costs and Revenues Assessed for 16-Year Investment Period

Data for the economic analysis of advance roading consist of the differences in costs and revenues between the 15-mile-per-year (16 years) and 30-mile-per-year (8 years) road programs.^{7/} Comparisons were limited to a 16-year investment period. Thinning during the 16-year investment period will influence future yields. But the difference in timing and amount of thinning under the two road programs is not great. Later, when certain basic study assumptions are relaxed, we shall see that what happens after the 16th year has no significant effect upon the economic feasibility of advance roading.

^{7/} The model for simulating road construction and timber harvesting, and for determining associated costs and revenues, was coded by Ed Holt, mathematician with the PNW Station, in FORTRAN IV for a Control Data Corporation (CDC) 6400 computer. A flow chart and program listing can be requested from the Director, Pacific Northwest Forest and Range Experiment Station, P.O. Box 3141, Portland, Oregon 97208.

Figure 3 shows the basic steps involved in compiling annual costs and returns. Both road right-of-way (step 1) and thinning harvest (step 2) volumes are determined before harvest cut volume (step 4). For example, although the conifer allowable cut in 1967 was 34.7 million board feet,^{8/} not all of this volume is allocated to harvest cutting. Some of the volume removed from thinning and road rights-of-way is included in the allowable cut. That is, the allowable cut is composed of three elements: (1) harvest cutting, (2) road right-of-way timber, and (3) "chargeable" thinning (fig. 4).

Because volume from all clearcutting operations--road rights-of-way as well as harvest cutting operations--is considered part of the annual allowable cut, timing of road construction affects the timing of harvest cutting during the 16-year investment period. The faster roads are constructed, the sooner road right-of-way timber will be harvested. Therefore, because the allowable cut is administratively fixed, that apportioned to final harvest cutting from an accelerated roadbuilding system would be less during the initial years of the investment period than from the base road plan. Appendix A describes how the acres to be clearcut for road rights-of-way and those accessible for thinning and harvest cutting were calculated.

Total Volume Harvested During
16-Year Investment Period
Differs Little Between Plans

Volumes logged from road rights-of-way and harvest cutting units were calculated from yield tables shown in appendix table 9. Unlike thinning and harvest cutting units, which include only merchantable types, roads cross a full range of age and forest type classes. Therefore, some conifer and hardwood logs from road rights-of-way are too small to sell. But regardless of the merchantability of road right-of-way timber, all conifers 10-inch d.b.h. and larger are chargeable to the allowable cut.

A 10-year cutting cycle was assumed when thinning volume was calculated for each road plan. That is, all accessible thinnable stands were programmed for thinning once per decade. The yield table and procedure used to determine acreage available annually for thinning are shown in Appendixes B and C.

Current BLM guidelines stipulate stands be thinned to the lesser of the following: removal of (1) 30 percent of existing basal area or (2) 60 percent of normal basal area. Doing so increases total yield during a rotation. However, the final harvest can be reduced by thinning. If so, the reduction in final harvest volume is "charged" as allowable cut and arbitrarily prorated at the time of thinning. Consequently, other things being equal, the more chargeable thinning in a particular year, the less allowable cut allocated to final harvest cutting operations.

^{8/} An allowable cut was calculated for this study. The Tillamook Resource Area does not have an official quota separate from that of the Columbia Master Unit of BLM's Salem District.

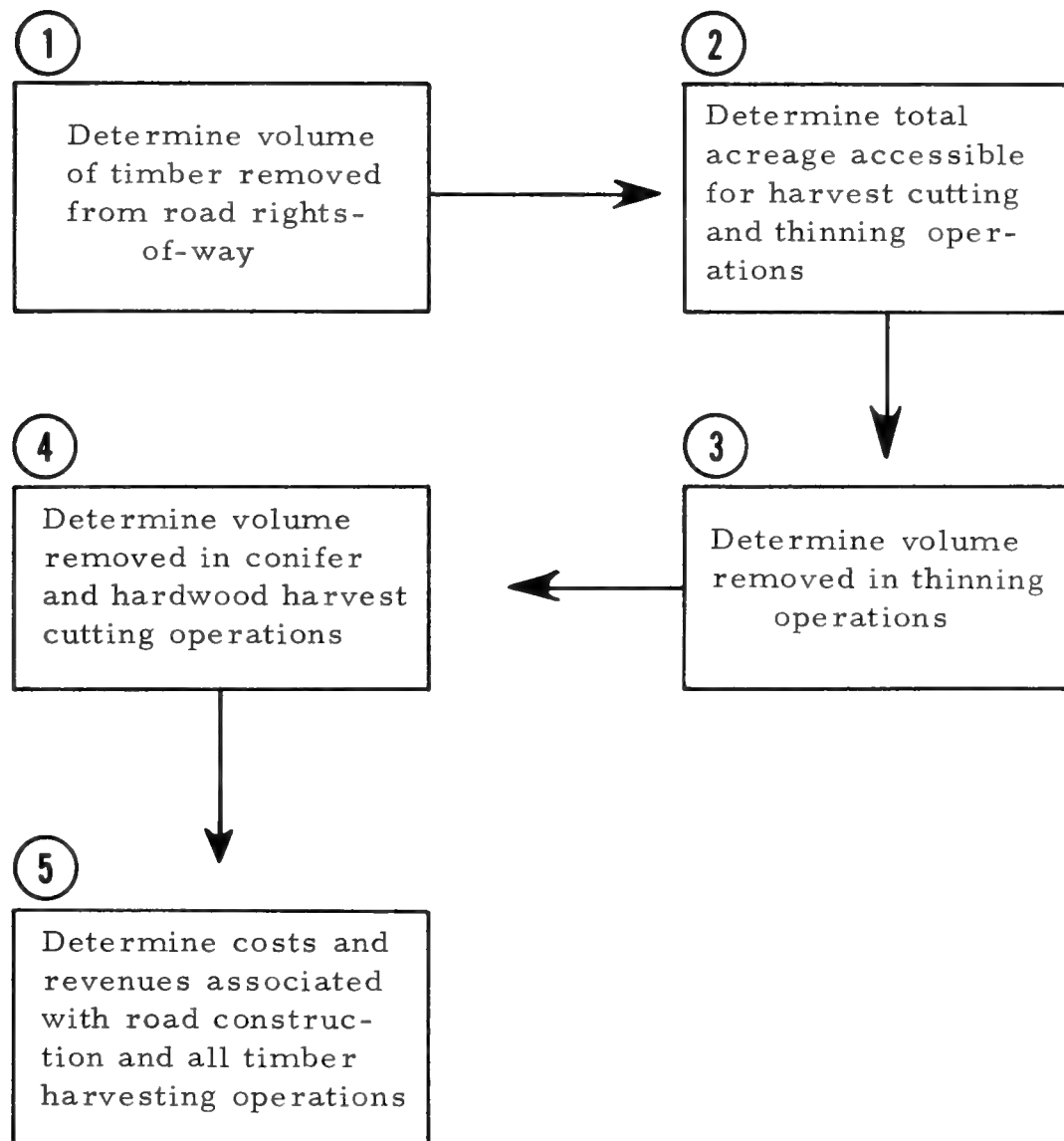


Figure 3.—Basic steps involved in deriving annual cost and revenue associated with road construction and timber harvesting activities on Tillamook Resource Area.

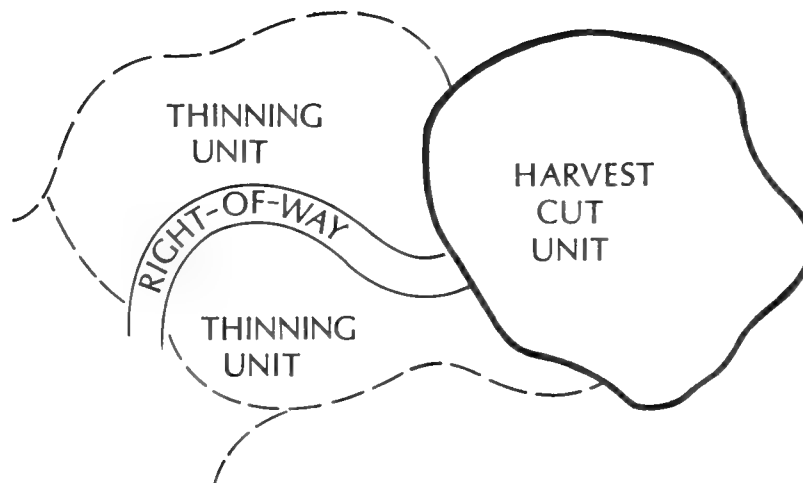


Figure 4.—The allowable cut is composed of (1) all volume removed from the harvest unit and (2) the road right-of-way, and (3) a fraction of the volume from thinning units.

An important observation is that a relatively large amount of thinning could be undertaken without building more roads in the Tillamook Resource Area. Approximately 5,000 acres were accessible for subsequent periodic thinning at the end of calendar year 1967. Total additional acreage exposed and thinned during the first decade would be 4,660 acres in the case of the 15-mile-per-year plan and 5,955 acres for the 30-mile plan. But by the end of the 16-year investment period, total acres initially thinned would be the same for both plans.

The "oldest-first" rule was used in scheduling harvest cutting operations. In addition, within age classes, lightly stocked stands were given precedence over more heavily stocked stands. As has been mentioned, the allowable cut allocated to final harvest cut operations is computed after deducting right-of-way and "chargeable" thinning volumes (see Appendix D for example of how the harvest-cut portion of the annual allowable cut is allocated to various age and stocking classes).

Figure 5 compares the two road programs regarding amount, timing, and composition of the conifer timber harvesting activity during the 16-year investment period. The most significant difference is the composition of the 34.7 million board-foot annual allowable cut. This difference results mainly from the timing of road right-of-way clearing.

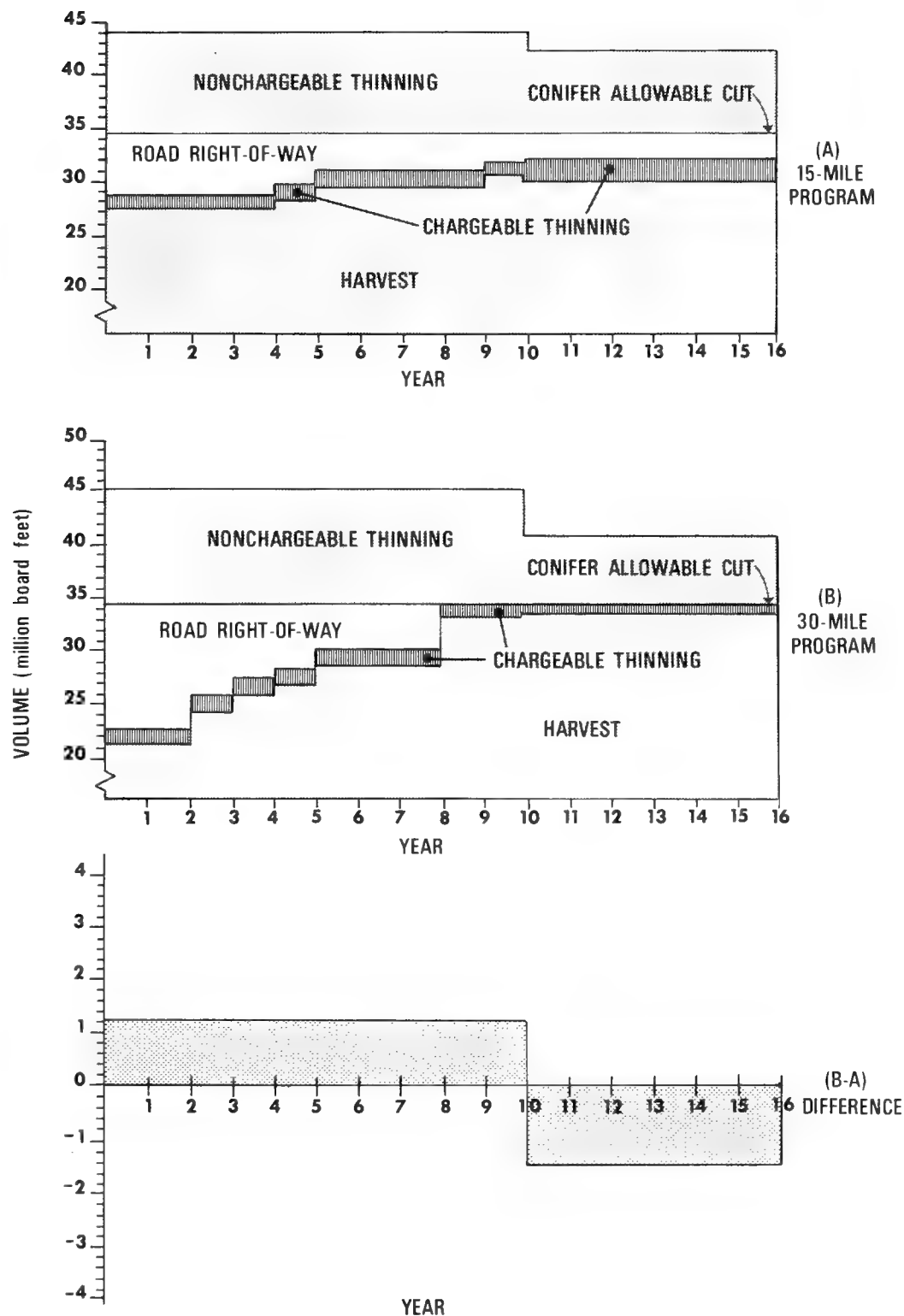


Figure 5.—Comparison of the volume, timing, and composition of conifer timber production under two road plans: 15 miles per year (A), and 30 miles per year (B); and the net differences between the plans (B-A).

The 30-mile program would generate slightly more conifer timber volume over the 16-year period--698 million board feet compared with 694 million board feet for the 15-mile program. However, from an economic standpoint, the composition and timing of the various allowable cut components are perhaps as important as the absolute difference in timber production. For example, the 30-mile program gains an economic advantage during the initial years of the investment period. A dollar of revenue accruing during the first years of the investment period would be worth more than the discounted value of a dollar revenue received several years later. Consequently, the physical relationship shown in figure 5 understates the economic advantage of the 30-mile over the 15-mile program.

Costs and Revenues Based on Tillamook Field Office Experience

Cost and revenue data used in the economic analysis of advance roading were developed from records maintained at the Tillamook field office. These data are shown in tables 3 and 4. Although certain data sources were fragmentary, the range of values used were considered representative of the end of calendar year 1967. Later, we shall examine the consequences of relaxing certain cost and revenue assumptions.

Only cost and revenue categories which vary with the rate of road construction and associated timber production activities were used in this analysis. These included all stumpage revenue but excluded certain operating costs. Not included, for example, were fixed office overhead costs. Costs for maintaining capital improvements as of the end of December 1967 (mainly roads) were also excluded.

Stumpage values synthesized from BLM records shown in table 4 are self-explanatory. Note that thinning sales are of two kinds; initial entry and first reentry. A limited acreage of the resource area was thinned prior to 1967 and would qualify for thinning again during the first decade. However, for the purposes of this analysis, we assumed no reentry thinning would be conducted until the second decade--after 1977.

A comparison of the various costs for the 15- and 30-mile programs is shown in figure 6. Total costs over the 16-year investment period were about the same for both programs--\$12.3 million versus \$12.9 million. Road maintenance costs accounted for most of the difference.

Road construction accounted for a major share of total costs--about 70 percent--for both programs, but the timing of this expenditure differed considerably. For the 30-mile program, all construction costs accrued during the first 8 years, whereas such costs were distributed over 16 years in the case of the 15-mile program. The difference in total discounted costs are greater than the absolute cost differentials shown in figure 6.

Table 3.--Costs associated with road construction and timber harvesting in Tillamook Resource Area

| Cost item | Unit of measure | Unit cost |
|---|--------------------------|-------------|
| Road construction: | | |
| Access roads | Per mile | \$60,000.00 |
| Low design-speed road | | 26,000.00 |
| Road maintenance: | | |
| Access roads | Per mile, | 500.00 |
| Low design-speed road | per year | 1,000.00 |
| Timber sale administration: ^{1/} | | |
| Harvest-cut sales | Per thousand board feet, | 2.50 |
| Road right-of-way sales | Scribner scale, | 2.50 |
| Thinning sales: | to 5-inch top | |
| 40 years old | | 4.25 |
| 50 years old | | 3.75 |
| 60 years old | | 3.25 |
| 70 years old | | 2.75 |
| 80 years old | | 2.25 |
| Regeneration | Per acre | 22.75 |

^{1/} Includes management planning, precruise and layout, cruise and appraisal, and contract preparation and administration.

Table 4.--Stumpage values used to compute revenues from logging operations, by type of sale^{1/ 2/}

| Stand age | Clearcut sales | | | Thinning sales ^{3/} | |
|--|-------------------------|-------|-------|------------------------------|---------------|
| | Conifer, stocking class | | Alder | Initial entry | First reentry |
| | 10-69 | 70+ | | | |
| - - - - - Dollars per million board feet - - - - - | | | | | |
| 40 | 20.00 | 25.00 | 2.50 | 20.00 | -- |
| 50 | 25.00 | 30.00 | 5.00 | 25.00 | 30.00 |
| 60 | 30.00 | 35.00 | 7.50 | 30.00 | 35.00 |
| 70 | 35.00 | 40.00 | 10.00 | 35.00 | 40.00 |
| 80 | 40.00 | 45.00 | 12.50 | 40.00 | 45.00 |
| 90+ | -- | 50.00 | -- | -- | -- |

^{1/} Assumes Scribner log scale to 5-inch top.

^{2/} Stumpage calculated as if roads were in place because all construction costs are treated separately.

^{3/} First reentry stumpage is higher than initial entry because of lower logging costs.

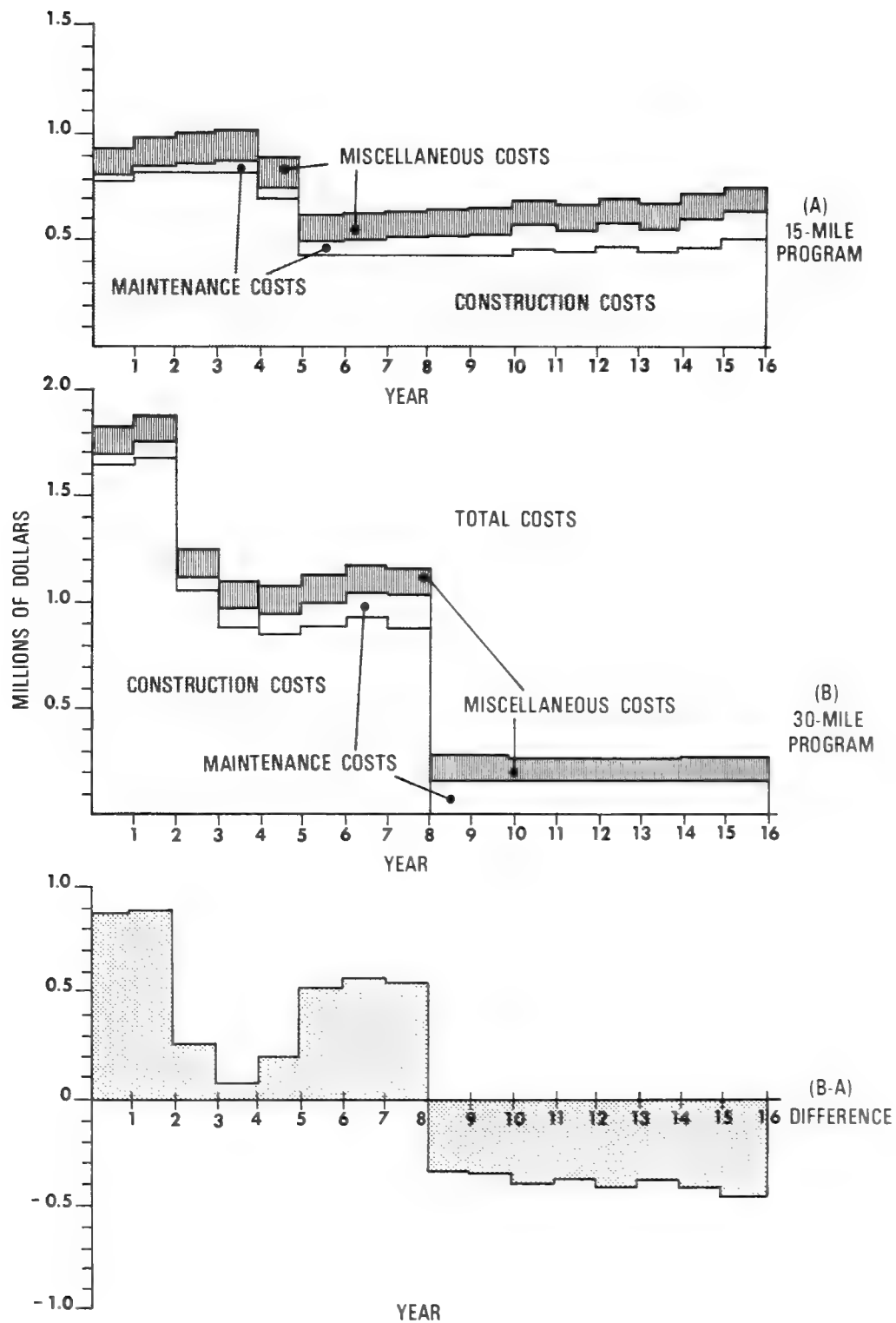


Figure 6.—Comparison of costs — road construction and maintenance, miscellaneous timber sale and reforestation, and total — under two road plans: 15 miles per year (A), and 30 miles per year (B), and net difference in total costs between the plans (B-A).

Total stumpage revenues, like total costs, were slightly less for the 15-mile program than for the 30-mile plan--\$30.2 million and \$30.4 million, respectively (fig. 7). Unlike costs, stumpage revenues were quite evenly distributed over the 16-year investment period for both programs. Note that although the 30-mile program generated more thinning revenue during the first 2 years than did the 15-mile program, the difference was not sufficient to compensate for lower harvest cut revenues. Consequently, total annual revenues were more for the 15- than the 30-mile program. Total revenues for the 30-mile program were also less for years 11, 12, 15, and 16. When coupled with lower initial construction and maintenance costs, the early revenue advantage of the 15-mile plan over the 30-mile plan is of particular importance from a present value standpoint.

ECONOMIC EFFICIENCY OF ALTERNATIVE ROAD PROGRAMS

The relative economic efficiency of the advance roading alternative compared with the base program was measured by the internal-rate-of-return criterion.^{9/} The internal rate of return earned by the additional road investments is the discount rate that equates the present value of incremental revenues to the present value of incremental costs. In other words, it is the rate which solves the following equation:

$$0 = \left[\begin{array}{c} \text{Sum of discounted} \\ \text{incremental} \\ \text{revenues} \end{array} \right] - \left[\begin{array}{c} \text{Sum of discounted} \\ \text{incremental} \\ \text{costs} \end{array} \right]$$

or,

$$0 = (PVR_{30} - PVR_{15}) - (PVC_{30} - PVC_{15}).$$

where PVR_{30} = present value of revenues of the accelerated road program,

PVR_{15} = present value of revenues of the base, or 15-mile road program,

PVC_{30} = present value of costs of the accelerated program,

PVC_{15} = present value of costs of base program.

The only data required for the rate-of-return analysis are the differences (B - A) shown in figures 6 (costs) and 7 (revenues).

^{9/} An internal-rate-of-return computer subroutine was used: Chappelle, Daniel E. A computer program for evaluating forestry opportunities under three investment criteria. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-78, 64 pp., illus. 1969.

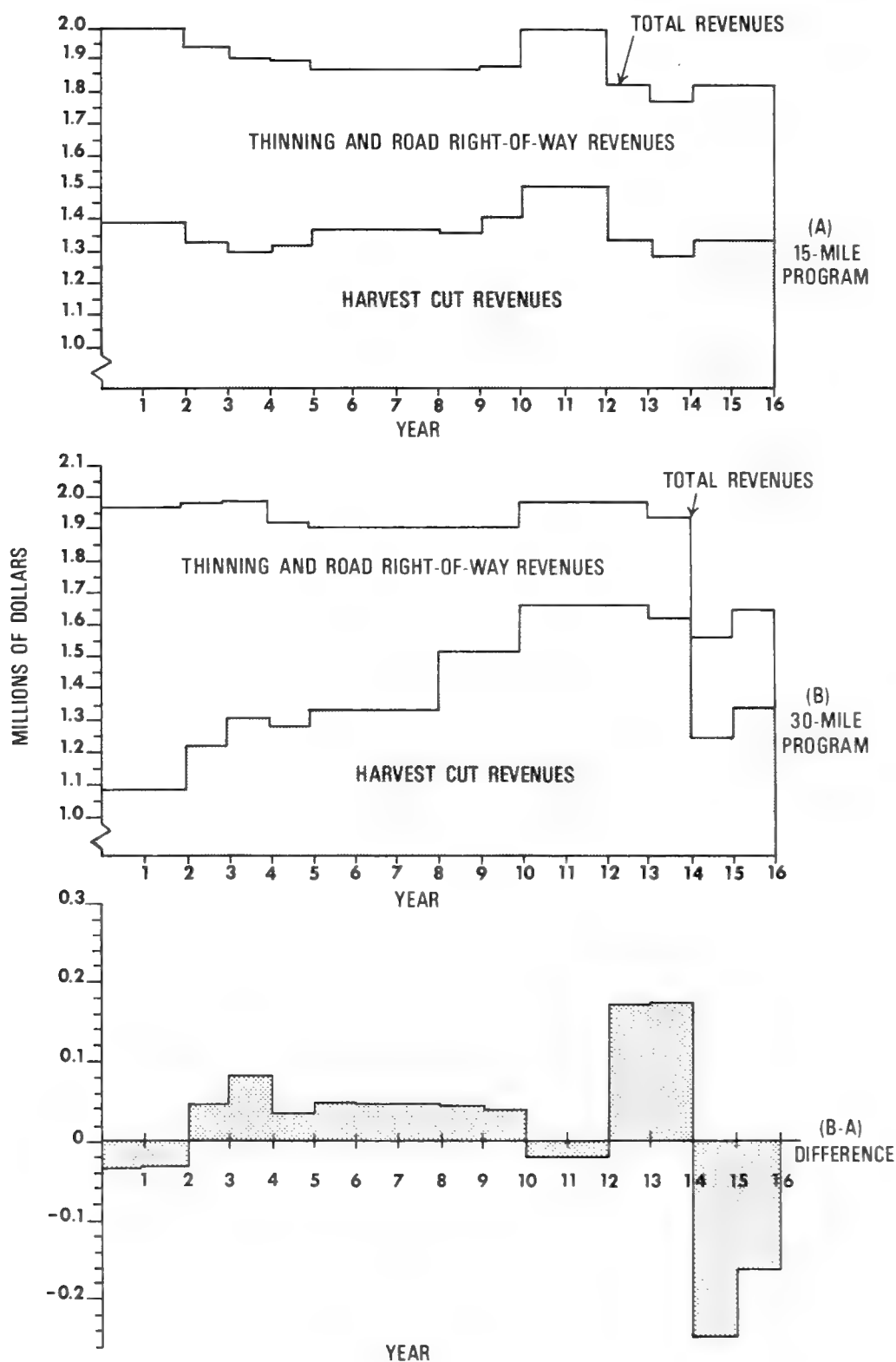


Figure 7.—Comparison of thinning and road right-of-way timber revenues, harvest cut revenues, and total revenues under two road plans: 15 miles per year (A), and 30 miles per year (B), and net difference in total revenues between plans (B-A).

Accelerated Road Program Economically Inferior to Base Program

Results of the economic analysis show the accelerated road construction program to be economically inferior to the current rate of road construction.^{10/} Incremental costs of undertaking an accelerated program would earn a minus 1.25-percent rate of return.

These results may seem incongruous in light of earlier studies, particularly those involving private lands. However, the findings are not too surprising when one considers that (1) public investment does not involve savings associated with tax treatment of private costs (i.e., private landowners can "expense" maintenance costs and amortize some construction costs), and (2) the "staggered" setting logging technique presently used by BLM requires that roads be constructed sooner than if a continually receding wall of timber were being logged. In essence, the results of this study show that, for the Tillamook Resource Area, wider spacing of staggered settings would not be economical.

Economic Effect of Changes in Basic Assumptions

Several kinds of questions can be raised regarding the results of this study. For example, how might lower road costs influence the results? How might inflationary trends affect the results? Would higher stumpage revenues for thinning enhance the economic feasibility of advance roading? A number of analyses in addition to the preceding were conducted in order to shed light on these and other questions. The results are summarized in table 5.

Analysis 1 demonstrates that advance roading would be even less desirable if road construction costs were decreased by 50 percent. These somewhat surprising results can be explained by the fact that (1) both the base and accelerated road programs would be affected by lower construction costs and (2) the timing of revenues is such that when costs are reduced, the net discounted present value of the 15-mile program is increased more than that for the accelerated program.

It has been hypothesized that advance roading would be more feasible during inflation than during a period of stability. Analyses 2, 3, and 4 verify this hypothesis. Costs, revenues, and both costs and revenues were increased 3 percent, compounded annually. This rate approximates the increase in costs for Federal-aid highway construction during the 7-year period, 1962-68.^{11/}

^{10/} A preliminary analysis has disclosed the current rate economically preferable to a slower rate of road construction.

^{11/} Bureau of Public Roads. Price trends for Federal-aid highway construction. U.S. Dep. Transp., Fed. Highway Admin., 2 pp., illus. 1969.

Table 5.--Effect of changes in basic study assumptions on the economic feasibility of advance roading
for management of young growth^{1/}

| Analysis | Change in basic assumption | | | | | | | | Rate of return (percent) |
|----------|---|--|---|---|--|---|--|---|--------------------------------|
| | Road construction costs reduced by 50 percent | All costs increased 3 percent, compounded annually | All revenues increased 3 percent, compounded annually | Residual effect of thinning included | | Thinning operability limits increased to 80 percent | Rotation age reduced to 70 years | Stumpage receipts increased ^{3/} | |
| | | | | All thinning valued at \$50 per MBF | Thinning valued inversely to age ^{2/} | | | | |
| 1 | X | -- | -- | -- | -- | -- | -- | -- | -2.66 |
| 2 | -- | X | -- | -- | -- | -- | -- | -- | 1.74 |
| 3 | -- | -- | X | -- | -- | -- | -- | -- | -1.04 |
| 4 | -- | X | X | -- | -- | -- | -- | -- | 1.92 |
| 5 | -- | -- | -- | X | -- | -- | -- | -- | -1.02 |
| 6 | -- | -- | -- | -- | X | -- | -- | -- | -.71 |
| 7 | -- | -- | -- | -- | -- | X | -- | -- | -1.17 |
| 8 | -- | -- | -- | -- | -- | -- | X | -- | -1.21 |
| 9 | -- | -- | -- | -- | -- | -- | -- | X | -.21 |
| 10 | -- | X | X | X | -- | X | -- | -- | 2.51 |
| 11 | -- | X | X | -- | -- | X | -- | X | 3.18 |

^{1/} Change in basic assumption indicated by (X); dash (--) indicates no change.

^{2/} Stumpage receipts plus an allowance for residual effects of thinning were assumed as follows: 40 years old, \$65 per MBF; 50 years old, \$60 per MBF; 60 years old, \$55 per MBF; 70 years old, \$50 MBF; 80 years old, \$45 per MBF.

^{3/} Stumpage receipts (see table 4) for thinning yields doubled; harvest cutting tripled.

Although advance roading would appear particularly attractive during periods of inflation, such an expectation would still not warrant increasing the rate of road construction for the Tillamook Resource Area.^{12/} Even with costs and revenues inflated, the rate of return for advance roading would not compare favorably with the current 5-1/2-percent guiding rates of discount used by the Department of Interior.^{13/}

Analyses 5 and 6 show that the inclusion of the estimated present value of future growth response to thinning would not appreciably affect the economic feasibility of advance roading. In analysis 5, the added value would equalize all thinning values at \$50 per thousand board feet. In analysis 6, stumpage plus an allowance for the residual effect of thinning would be greatest for the 40-year-old stands (\$65 per MBF) and least for the 80 (\$45 per MBF).

Logging equipment is being developed which may permit thinning on slopes greater than 45 percent. Analysis 7 demonstrates the economic effect of being able to thin 80 percent rather than 60 percent of thinnable age classes. The change in operability limits has only a slight positive effect upon the economic feasibility of advance roading. Likewise, reducing rotation age from 80 to 70 years (the allowable cut would increase from 34.7 million to 38.4 million board feet) would not significantly influence the economics of advance roading (analysis 8).

Stumpage values in 1967 were considerably lower than early 1969 levels. Analysis 9 shows that increasing stumpage values in line with more current market conditions enhances the economic efficiency of advance roading, but the rate of return earned is still negative. In fact, even if one could justify all the changes which have a positive effect upon the economics of advance roading--as was presumed in analyses 10 and 11--investments in advance roading would not compare favorably with current guiding rates of discount.

^{12/} McKean, Roland N. Efficiency in government through systems analysis with emphasis on water resources development. 336 pp. New York: John Wiley & Sons. 1958. McKean (p. 182) objects to using inflated prices because doing so represents "...a bet on inflation...by government on its own failure to win in its struggle for stability--a type of wagering that is frowned upon in most contests."

^{13/} Based on BLM Director's Information Memo No. 69-136 (unpublished), October 23, Washington, D.C. 1969. See also U.S. Congress. Interest rate guidelines for Federal decision making. Hearing before subcommittee of Joint Economic Committee, 90th Congress, January 29. 1968.

DISCUSSION OF STUDY FINDINGS

The results of this analysis are quite conclusive--accelerating the current rate of advance roading for the management of young-growth timber in the Tillamook Resource Area does not represent an attractive investment opportunity. Aside from the fact that the Federal Government must currently borrow at a higher interest rate than that earned by the most "optimistic" assessment of advance roading opportunities in the Tillamook area, the Bureau of Land Management undoubtedly has many more lucrative investment options.

In view of the cost-price relationships examined in this study, accelerating road construction would not be a profitable way to increase output from young-growth forests in the Tillamook area. The basic reason for the poor showing is that the current rate of road construction is providing considerable opportunity to thin conifer stands and accelerated road construction would not generate enough more timber to justify its cost.

APPENDIX A

PROCEDURE FOR DETERMINING ACREAGE ACCESSIBLE FOR THINNING AND HARVEST CUTTING OPERATIONS

Acreage accessible for thinning or harvest cutting operations for each of the 16 years in the investment period was calculated by use of the following equation:

$$\left[\begin{array}{c} \text{Accessible} \\ \text{acres} \\ \text{this year} \end{array} \right] = \left[\begin{array}{c} \text{Acres} \\ \text{accessible} \\ \text{end of} \\ \text{last year} \end{array} \right] + \left[\begin{array}{c} \text{Miles of} \\ \text{road built} \\ \text{this year} \end{array} \right] \left(\left[\begin{array}{c} \text{Total acres per} \\ \text{mile in tributary} \\ \text{cutting units} \end{array} \right] - \left[\begin{array}{c} \text{Acres cleared} \\ \text{per mile of} \\ \text{right-of-way} \end{array} \right] \right)$$

Note the relationship between acreage cleared for road rights-of-way and acreage accessible in a particular year for thinning and harvest cutting.

With the above equations and values from tables 1, 6, and 7, acreage in the 60-year-old, 10- to 69-percent stocking class accessible as the result of constructing 15 miles of new road during the first year of the investment period was calculated as follows:

$$\begin{array}{ccccccc} 185.71 & = & 165 & + & 15 \times & [1.4948 & - & 0.1143] \\ \text{(table 8)} & & \text{(table 1)} & & & \text{(table 6)} & & \text{(table 7)} \end{array}$$

This value as well as those for each age, type, and stocking class are shown in table 8.

Table 6.--*Distribution of total acreage of commercial forest land exposed for right-of-way, thinning, and harvest cutting operations per mile of road constructed, by phase, type, age, and stocking class*

| Age | Douglas-fir stocking class | | | Alder (all stocking classes) |
|-------------------------------|----------------------------|-----------|--------------|---------------------------------------|
| | 10-69 | 70+ | | |
| | | Thinnable | Nonthinnable | |
| Phase I (First 70 miles) | | | | |
| 30 | 0.0077 | 1.2608 | 0.8406 | 0.6714 |
| 40 | .2013 | 1.4677 | .9785 | 4.7663 |
| 50 | .0564 | .3185 | .2124 | 1.7051 |
| 60 | 1.4948 | 6.1798 | 4.1199 | 4.0330 |
| 70 | 2.4030 | 25.8937 | 17.2624 | 3.5359 |
| 80 | 0 | 0 | 22.2110 | 4.4118 |
| 90+ | 0 | 0 | 11.1142 | 0 |
| Phase II (Second 70 miles) | | | | |
| 30 | 1.0797 | 1.1718 | .7812 | 1.5356 |
| 40 | 1.4806 | 2.8516 | 1.9011 | 11.5334 |
| 50 | 0 | .0323 | .0215 | 2.5948 |
| 60 | 8.5801 | 12.8994 | 8.5996 | 2.8661 |
| 70 | 14.7789 | 19.3116 | 12.8744 | 2.5684 |
| 80 | 0 | 0 | 16.4223 | .4657 |
| 90+ | 0 | 0 | 3.3757 | 0 |
| Phase III (Last 100 miles) | | | | |
| 30 | .0103 | 2.0364 | 1.3576 | 1.9371 |
| 40 | .5811 | 2.6809 | 1.7873 | 5.7670 |
| 50 | .3998 | 2.2219 | 1.4812 | 10.2235 |
| 60 | 2.6922 | 3.1450 | 2.0966 | 9.3567 |
| 70 | 1.2485 | 6.7611 | 4.5074 | 4.9687 |
| 80 | 0 | 0 | 8.3030 | .6673 |
| 90+ | 0 | 0 | 3.7219 | 0 |

Table 7.--Acres of commercial forest land cleared for right-of-way per mile of road constructed by type, age, stocking class, and phase of road construction^{1/}

| Age ^{2/} | Douglas-fir stocking class | | | Alder (all stocking classes) |
|-------------------|----------------------------|-------------------|--------------|---------------------------------------|
| | 10-69 | 70+ ^{3/} | | |
| | | Thinnable | Nonthinnable | |

Phase I
(First 70 miles)

| | | | | |
|-------|-------|--------|--------|--------|
| 30 | 0 | 0.0964 | 0.0643 | 0 |
| 40 | .0154 | .1122 | .0748 | .2979 |
| 50 | .0043 | .0244 | .0162 | .1210 |
| 60 | .1143 | .4724 | .3150 | .3051 |
| 70 | .1837 | 1.9796 | 1.3197 | .2675 |
| 80 | 0 | 0 | 1.6980 | .3372 |
| 90+ | 0 | 0 | .8497 | 0 |
| Total | .3177 | 2.6850 | 4.3377 | 1.3287 |

Phase II
(Second 70 miles)

| | | | | |
|-------|--------|--------|--------|--------|
| 30 | .0529 | .0574 | .0384 | .0754 |
| 40 | .0726 | .1399 | .0933 | .5661 |
| 50 | 0 | .0016 | .0010 | .1274 |
| 60 | .4212 | .6332 | .4221 | .1407 |
| 70 | .7254 | .9478 | .6320 | .1260 |
| 80 | 0 | 0 | .8060 | .0228 |
| 90+ | 0 | 0 | .1656 | 0 |
| Total | 1.2721 | 1.7799 | 2.1584 | 1.0584 |

Phase III
(Last 100 miles)

| | | | | |
|-------|-------|--------|--------|--------|
| 30 | .0008 | .1526 | .1017 | .1451 |
| 40 | .0435 | .2009 | .1339 | .4320 |
| 50 | .0300 | .1664 | .1109 | .7659 |
| 60 | .2017 | .2356 | .1570 | .7009 |
| 70 | .0935 | .5065 | .3376 | .3722 |
| 80 | 0 | 0 | .6221 | .0499 |
| 90+ | 0 | 0 | .2788 | 0 |
| Total | .3695 | 1.2620 | 1.7420 | 2.4660 |

^{1/} Not included are the 10- to 20-year age classes and nonstocked forest land, because they will not produce merchantable timber during the 16-year investment period.

^{2/} Acreage in 30-year-old stands does not qualify for thinning during first 10 years but will thereafter. Likewise, some 70-year-old stands will age 10 years before being accessible and/or considered for clearcutting.

^{3/} The degree of slope distinguishes thinnable from nonthinnable stands. Current technology limits thinning to slopes 45 percent or less.

Table 8.--*Total acres of commercial forest land accessible for thinning and harvest cutting operations as a result of 15 miles of road constructed during first year of the investment period*^{1/}

| Age | Douglas-fir stocking class | | | Alder (all stocking classes) |
|-----|----------------------------|-----------|--------------|---------------------------------------|
| | 10-69 | 70+ | | |
| | | Thinnable | Nonthinnable | |
| 30 | 129.12 | 594.47 | 396.47 | 421.07 |
| 40 | 166.79 | 470.33 | 313.56 | 975.03 |
| 50 | 90.78 | 57.41 | 38.94 | 128.76 |
| 60 | 185.71 | 1,074.61 | 716.07 | 158.92 |
| 70 | 553.29 | 3,899.71 | 2,600.14 | 154.03 |
| 80 | 0 | 0 | 1,293.69 | 108.12 |
| 90+ | 0 | 0 | 748.97 | 0 |

^{1/} Only a percentage of total accessible acres are thinned or harvest cut in a particular year.

APPENDIX B

YIELD TABLES FOR CLEARCUTTING AND THINNING OPERATIONS

Table 9.--*Clearcut yield table for average Douglas-fir and alder sites for Tillamook Resource Area by age and stocking class*

| Age | Douglas-fir ^{1/} stocking class | | Alder ^{2/} |
|---|--|--------|---------------------|
| | 10-69 | 70+ | |
| - - - - - Board feet ^{3/} per acre - - - - - | | | |
| 30 | 3,085 | 13,631 | 1,920 |
| 40 | 13,664 | 25,146 | 5,200 |
| 50 | 23,756 | 35,633 | 8,240 |
| 60 | 33,358 | 45,092 | 10,880 |
| 70 | 42,472 | 53,522 | 13,120 |
| 80 | 51,097 | 60,924 | 14,240 |
| 90 | -- | 67,298 | 14,720 |
| 100+ | -- | 76,964 | -- |

^{1/} Data from Bureau of Land Management, Salem District, inventory plot data for site class 160. Because of insufficient data, a yield equation could not be developed for the "10-39" stocking class.

^{2/} From table 13, Worthington, N. P., et al. Normal yield tables for red alder. USDA Forest Serv. Res. Pap. 36, 1960. Values shown are 80 percent of site index 70 yields. This adjustment is necessary because basic yield table is for fully stocked stands.

^{3/} Scribner scale to 5-inch top, 10-inch minimum d.b.h.

Table 10.--*Douglas-fir thinning yield tables for site class 160,*^{1/}
board feet, Scribner scale to 5-inch top, 7-inch minimum
d.b.h.

| 80-YEAR ROTATION | | | | |
|---------------------|------------------|------------|-----------------------------|------------|
| Age when thinned | Type of thinning | | | |
| | Initial | | First reentry ^{2/} | |
| | Nonchargeable | Chargeable | Nonchargeable | Chargeable |
| 40 | 5,485 | 978 | -- | -- |
| 50 | 8,653 | 0 | 6,361 | 978 |
| 60 | 10,567 | 0 | 6,689 | 0 |
| 70 | 9,916 | 2,070 | 6,160 | 0 |
| 80 ^{3/} | 8,912 | 4,139 | 4,244 | 2,070 |

| 70-YEAR ROTATION | | | | |
|------------------|--------|-------|-------|-------|
| 40 | 4,822 | 1,642 | 0 | 0 |
| 50 | 7,867 | 786 | 5,697 | 1,642 |
| 60 | 10,567 | 0 | 5,903 | 786 |
| 70 | 9,190 | 2,796 | 6,160 | 0 |
| 80 ^{3/} | 7,460 | 5,592 | 3,518 | 2,796 |

^{1/} Based on thinning guidelines developed by Tillamook project staff. Chargeable volumes (i.e., the bookkeeping adjustment expressing reduction in final harvest cutting due to thinning) were arbitrarily prorated to various thinning ages.

^{2/} No reentry in 40-year-old stands since younger age classes (i.e., than 40 years old) do not qualify for commercial thinning.

^{3/} No stands typed as 80 years at outset of investment period will be thinned. However, stands now 70 years old and not thinned during first decade will be 80 years old by the time they are thinned during the second decade.

APPENDIX C

PROCEDURE USED TO DETERMINE ACRES THINNED DURING 16-YEAR INVESTMENT PERIOD

Regardless of road plan, all qualified stands (i.e., all 40- to 70-year-old stands, 60 percent and more of normal basal area) would be thinned at least once during the 16-year investment period. But with a 10-year cutting cycle, the rate would differ as shown below:

| <u>Age at beginning of first decade</u> | <u>Total acres accessible for initial thinning during first decade</u> | |
|---|--|------------------------|
| | <u>15-mile program</u> | <u>30-mile program</u> |
| 40 | 759 | 982 |
| 50 | 96 | 281 |
| 60 | 2,276 | 2,538 |
| 70 | 6,562 | 7,191 |

For any year, acres thinned would be one-tenth of the value shown for a particular age and road plan.

In the case of the 30-mile program, with one exception, all stands would be thinned during the first decade. Stands 30 years of age at the outset of the investment period would not qualify for thinning until the 11th year. Acres to be thinned initially during the last 6 years of the investment period are shown below:

| <u>Age at beginning of second decade</u> | <u>Total acres available for initial thinning during last 6 years</u> | |
|--|---|------------------------|
| | <u>15-mile program</u> | <u>30-mile program</u> |
| 40 | 924 | 924 |
| 50 | 223 | -- |
| 60 | 185 | -- |
| 70 | 262 | -- |
| 80 | 563 | -- |

For both road programs, the acres of "first reentry" thinning for a particular age class for the 11th year will be the same acreage thinned initially for year 1; for year 12, the same as year 2, etc. However, acres thinned initially during the first decade will, of course, age 10 years. So a stand classified 70 years old, for example, at the time of initial thinning, would be 80 years old at the time of the first reentry thinning.

APPENDIX D

PROCEDURE FOR ALLOCATING HARVEST CUT BY AGE AND STOCKING CLASSES

To illustrate how the harvest cut is allocated to age and stocking classes, we will examine the 14th year of the 15-mile-per-year road program. Keep in mind that the oldest, and, within an age class, the lowest stocked stands are arbitrarily given first cutting priority.

First, let us consider the conifer acres accessible for logging (i.e., net of road right-of-way clearcutting and thinning) in the 80-100 age classes. Approximately 30.3 of the 34.7 million feet remain after right-of-way cutting and thinning to be allocated to these age classes:

| <u>Age</u> | <u>Conifer stocking class</u> | | |
|------------|-------------------------------|---------------------|------------------|
| | <u>10-69</u> | <u>70+</u> | |
| | | <u>Nonthinnable</u> | <u>Thinnable</u> |
| | <u>----- Acres -----</u> | | |
| 80 | 1,552.72 (3) | 4,625.84 (4) | 6,938.27 (5) |
| 90 | 0 | 115.21 (2) | 0 |
| 100 | | 51.65 (1) | |

The numbers in parentheses indicate cutting priorities. Following this order, volume accessible for harvest cutting was determined by multiplying acres accessible by corresponding values in table 9 (i.e., per-acre volumes):

| | | <u>Board feet</u> |
|--|---|-------------------|
| 1. Volume to be allocated | = | 30,263,008 |
| 2. Volume accessible in 100-year-old class 76,964 x 51.65 | = | <u>-3,974,921</u> |
| 3. Volume to be allocated (1-2=3) | | 26,288,087 |
| 4. Volume accessible in 90-year-old class 67,298 x 115.21 | = | <u>-7,753,638</u> |
| 5. Volume to be allocated (3-4=5) | = | 18,534,449 |

Similarly, the remaining volume was allocated to the 80-year-old age class. Table 11 shows how not only the "allowable" conifer harvest cut was allocated by age and stocking classes, but also the road right-of-way cut. In addition, the allocation of the 1.5 million-board-foot hardwood allowable cut is shown.

Table 11.--Allocation of conifer and hardwood allowable cuts to harvest and road right-of-way cuttings, by age and stocking class

| Age | Type of cut ^{1/} | Conifer stocking class | | | Hard-woods |
|-----|---------------------------|------------------------|-----------|--------------|------------|
| | | 10-69 | 70+ | | |
| | | | Thinnable | Nonthinnable | |

- - Board feet, Scribner scale, to 5-inch top - -

| | | | | | |
|------|---|------------|---------|-----------|---------|
| 30 | H | 0 | 0 | 0 | 0 |
| | R | 0 | 0 | 0 | 0 |
| 40 | H | 0 | 0 | 0 | 0 |
| | R | 164 | 57,559 | 38,360 | 11,318 |
| 50 | H | 0 | 0 | 0 | 0 |
| | R | 15,501 | 107,380 | 71,569 | 53,395 |
| 60 | H | 0 | 0 | 0 | 0 |
| | R | 15,011 | 112,550 | 75,011 | 124,995 |
| 70 | H | 0 | 0 | 0 | 0 |
| | R | 128,499 | 189,147 | 126,044 | 137,937 |
| 80 | H | 18,534,510 | 0 | 0 | 945,423 |
| | R | 71,664 | 462,870 | 308,519 | 79,502 |
| 90 | H | 0 | 0 | 7,753,638 | 136,405 |
| | R | 0 | 0 | 627,991 | 11,025 |
| 100+ | H | 0 | 0 | 3,974,921 | 0 |
| | R | 0 | 0 | 321,863 | 0 |

^{1/} H = Harvest cut.
R = Road right-of-way cut.

Schallau, Con H.

1970. An economic analysis of accelerating road construction on the Bureau of Land Management's Tillamook Resource Area. USDA Forest Service Res. Pap. PNW-98, 29 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

Acceleration of road construction in the Bureau of Land Management's Tillamook Resource Area would not be economically feasible. Although doubling the current rate of construction would increase thinning yields, added stumpage revenues would not compensate for higher interest, timber sale administration, and maintenance charges. In fact, investment in such a plan would earn a minus 1.25-percent rate of return.

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100 E 10

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